



**ADVANCED COOLING  
STRATEGIES/TECHNOLOGIES  
CONFERENCE**

**Closed-Loop Evaporative Cooling Systems  
for Water Limited Power Plants**

Peter G. Demakos, PE  
Niagara Blower Co.

# **Agenda**

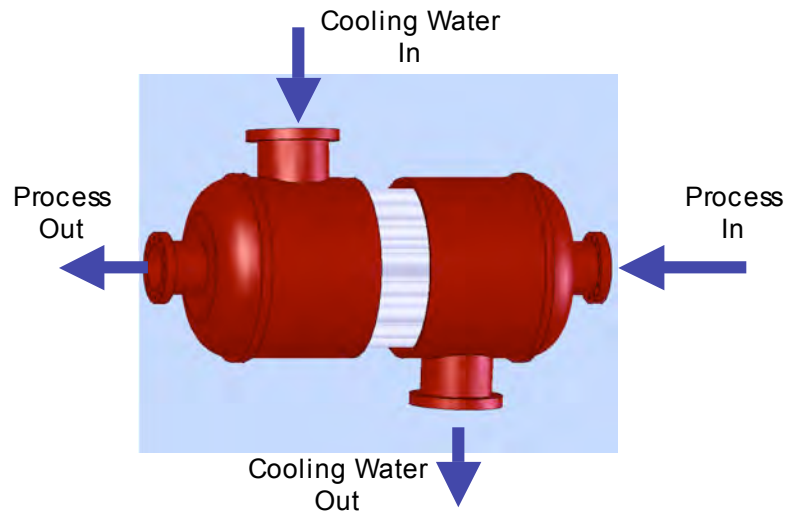
- **Closed-Loop (WSAC) Systems**
- **Applications**
- **Water Usage**
- **Advanced Technologies**
- **Installations**
- **Summary**

# What is a Wet Surface Air Cooler?

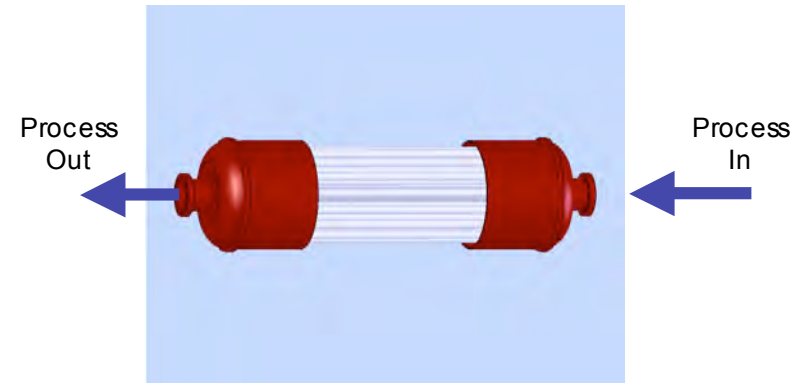
- Heat Removal Device
- Direct Liquid/Vapor Cooling
- Where is it applicable?
  - Liquid Cooling
    - Up to max inlet temp of 180° F
  - Turbine exhaust vacuum steam condensing
    - As low as 2.0” HgA
  - Hydrocarbon & Ammonia condensing

# How Does the WSAC Work?

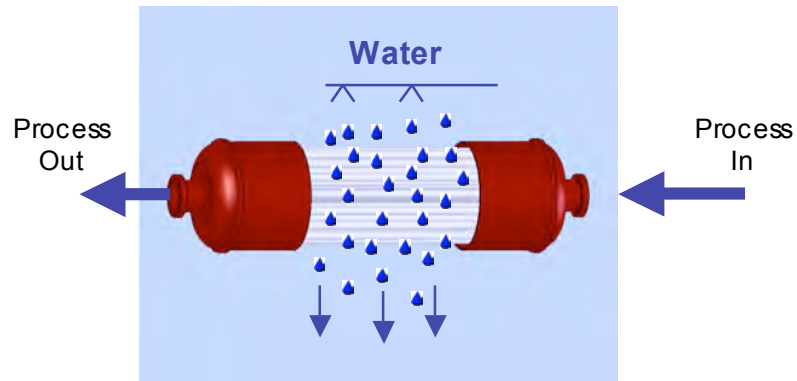
1.) Typical Shell & Tube Heat Exchanger



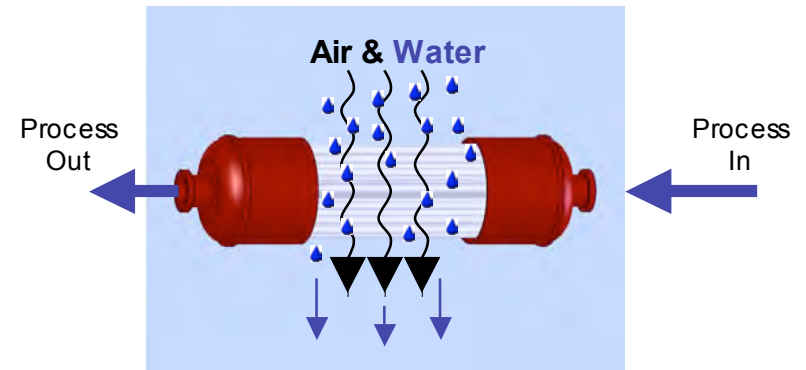
2.) Remove "Shell" Exposing Tubes



3.) Spray Water Directly Over the Exposed Tubes



4.) Air is Induced Over Tubes in the Same Direction as the Water



# How Does the WSAC Work?

① Air is induced downward over tube bundles

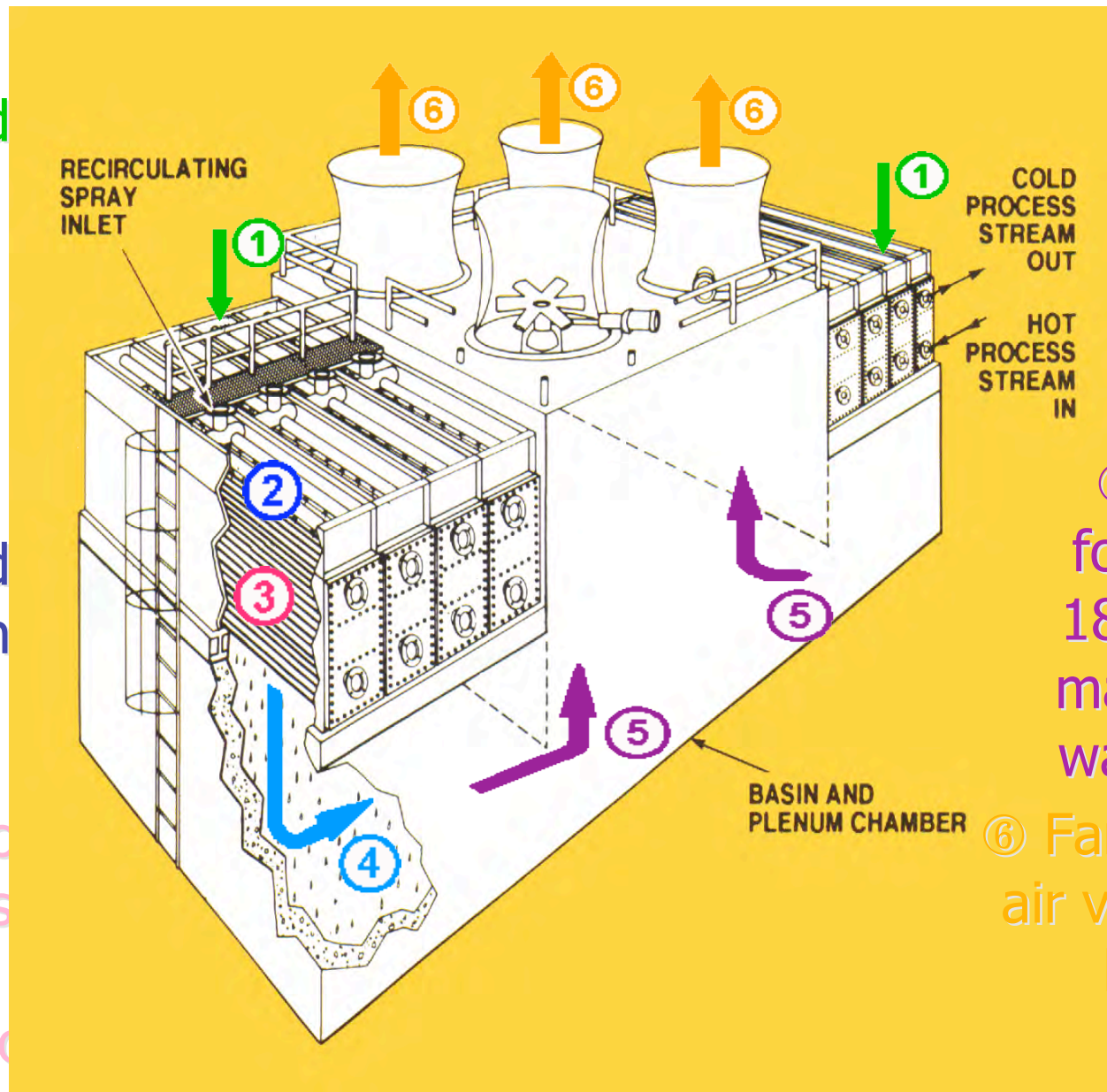
② Water flows downward along with the air

③ Heat from the process stream is released to cascading water

④ Heat is transferred from the cascading water to the air stream via vaporization

⑤ Air stream forced to turn 180° providing maximum free water removal

⑥ Fans discharge air vertically at a high velocity preventing recirculation



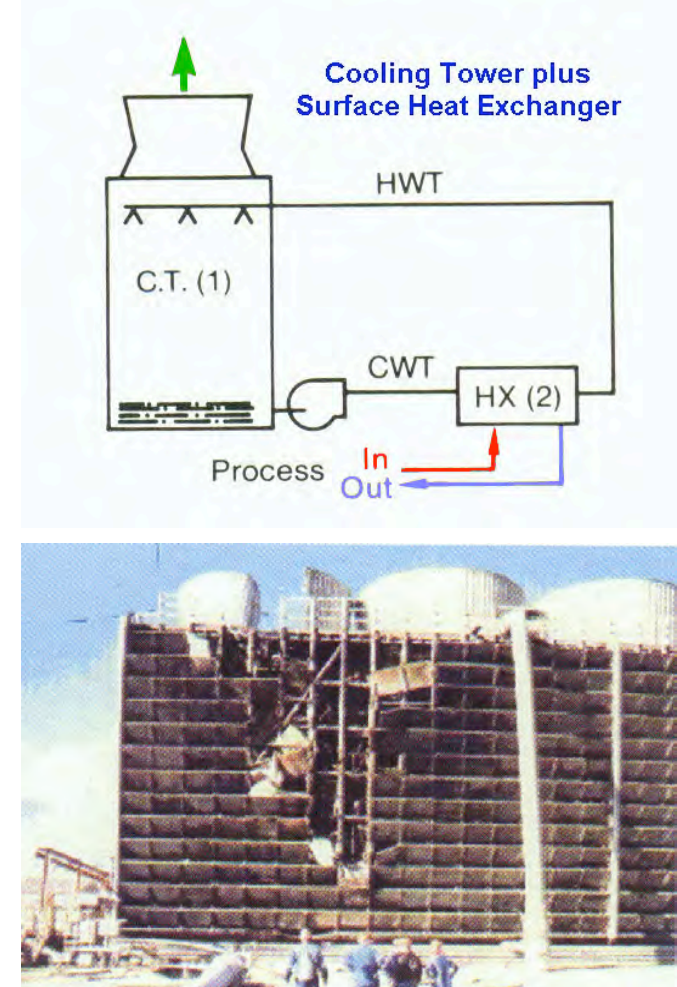
# **WSAC** **REPLACES**

**Cooling Tower**  
+  
**Heat Exchanger**      *or*      **Air Cooled**  
+      **Heat Exchanger**  
**Pumps & Piping**  
**Loop**

# Alternative Technology

•Design Conditions: 95°F DB 75°F WB

Thermal System	Two Stage (Latent/Sensible)
Practical Approach Temp.	(1) CWT approach to WB...10°F (2) CPT approach to CWT...5°F
Coldest Practical Final Process Temp. (CPT)	90°F
Thermal System Responsibility	Divided between Cooling Tower and Heat Exchanger
Process Side Access for Cleaning	Available but requires special consideration since cooling tower water should also be accessible
Retubability in Place	Available
Water Treatment	HX allows for only 4-6 cycles of concentration (High blowdown rate)

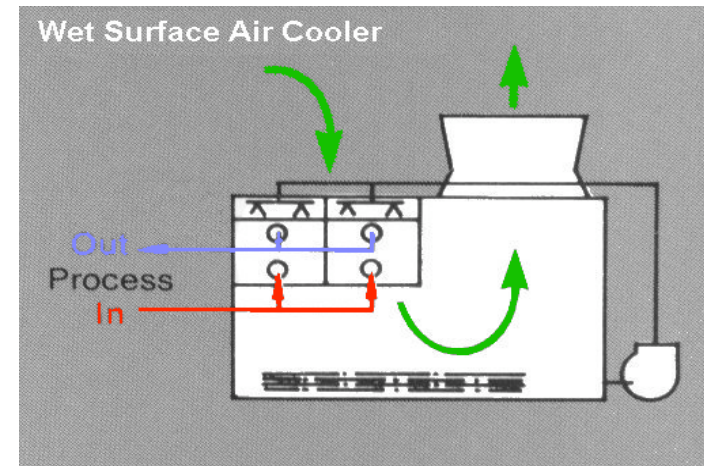




# WSAC Technology

•Design Conditions: 95°F DB 75°F WB

Thermal System	One Stage (Latent)
Practical Approach Temp.	Cpt approach to WB...10°F
Coldest Practical Final Process Temp. (CPT)	85°F
Thermal System Responsibility	Single Source
Process Side Access for Cleaning	Full Mechanical accessibility
Retubability in Place	Standard Practice
Water Treatment	Able to run high cycles of concentration

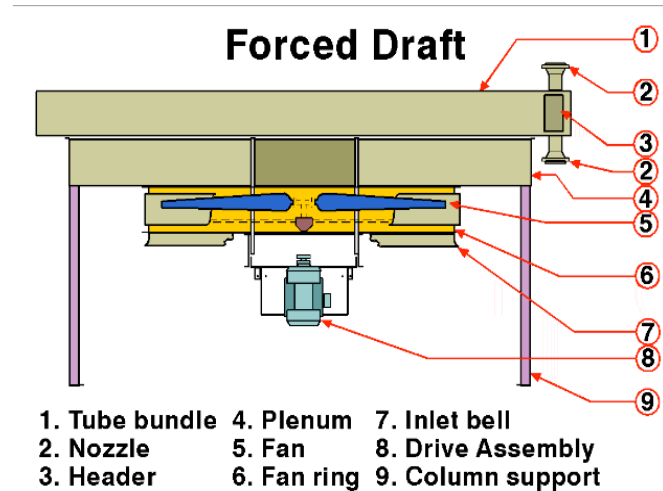




# Alternative Technology

•Design Conditions: 95°F DB 75°F WB

Thermal System	One Stage (Sensible)
Practical Approach Temp.	<b>CPT approach to DB...25°F</b>
Coldest Practical Final Process Temp. (CPT)	<b>120°F</b>
Thermal System Responsibility	Single Source
Process Side Access for Cleaning	Full Mechanical accessibility if removable headers exist
Retubability in Place	Not Normally Available
Water Treatment	None required Close fin spacing (8 or more fin/inch) requires frequent air side cleaning in most industrial atmospheres



# Closed-Loop, Evaporative Cooling Systems

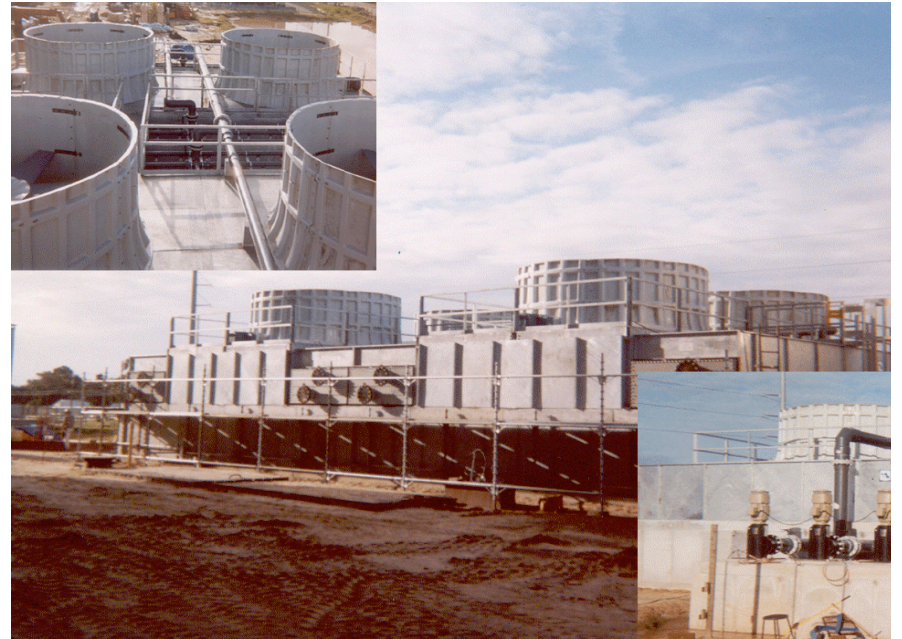
- Open Loop Water Never Contaminates the Closed Loop System
- Thermal Performance is Maintained
- Poor Quality Water can be Used as Makeup Source
- Higher Cycles of Concentration
- Less Site Water and Blowdown

**WSAC IS A WATER-CONSERVING SYSTEM**

# Unit Types



Packaged Unit



Field Erected Unit

# General Specifications for WSAC

- Tube Bundles

Serpentine

or Straight Through





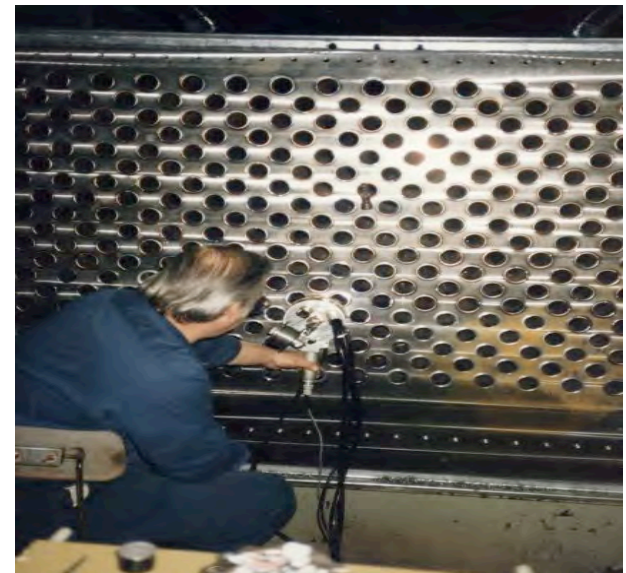
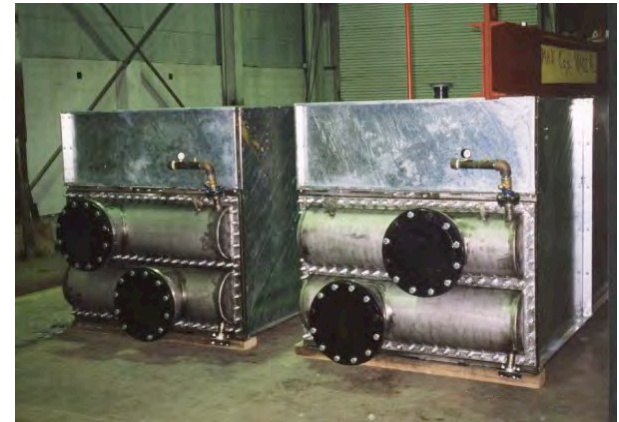
# General Specifications for WSAC

- Tube Bundles
  - Serpentine
    - Constructed with a continuous tube circuit
    - Various tube materials available
    - Carbon steel bundles all H.D.G.A.F.
    - Lowest cost arrangement
    - Highest pressure rating - up to 2500 psi
    - ASME Code design available



# General Specifications for WSAC

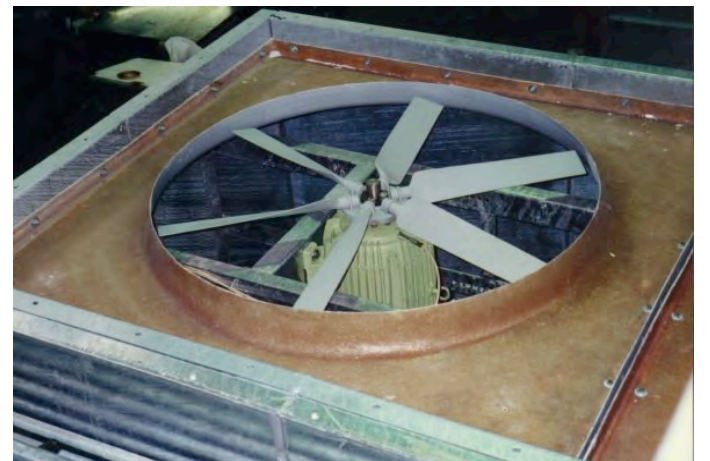
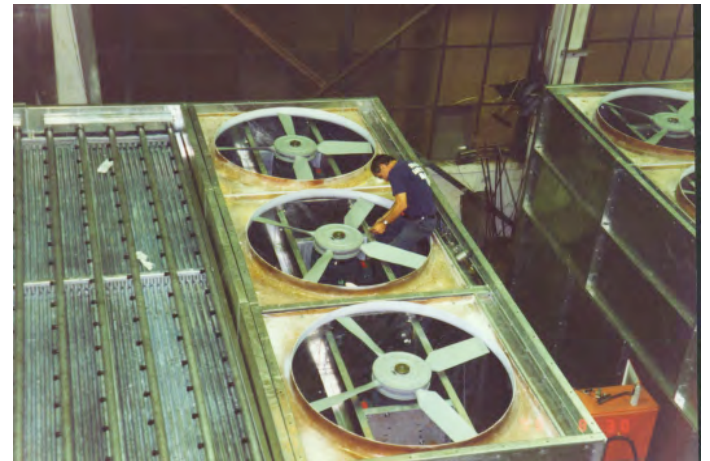
- Tube Bundles
  - Straight Through / Cleanable
    - Complete internal access for inspection and cleaning
    - Offers lowest process side pressure drop
    - Various tube materials available
    - Tube sheet thickness designed to TEMA standards
    - Bundles can be retubed using existing headers
    - ASME Code design available





# General Specifications for WSAC

- Fan System
  - Direct Drive
    - 5 ft. diameters and smaller
    - Plastic fan blade construction
    - Carbon steel construction of all fan supports, motor brackets, and fan exhaust rings
    - Adjustable pitch design
    - Fans directly connected to Totally Enclosed Air Over (TEAO) motor



# General Specifications for WSAC

- Fan System
  - Right Angle Drive
    - 6 ft. diameters and larger
    - Fiberglass-reinforced epoxy fan blade construction
    - Access door provided for fan system maintenance
    - Motors are TEFC, NEMA approved



# General Specifications for WSAC

- Spray Water Distribution System
  - Low-pressure / High-flow design
  - Full flooded spray pattern
  - Heavy duty construction
    - PVC pipe for assembled on site units
    - Galvanized carbon steel for factory assembled units
    - Use large orifice non-clogging nozzles



# **WSAC Applications in the Power Industry**

- Simple Cycle Auxiliary Loop Water Cooling
- Combined Cycle Auxiliary Loop Water Cooling
- Vacuum Steam Condensing
- Gas Turbine Inlet Air Cooling System  
Condensers
- As a First-Stage Evaporator in Zero Discharge  
Plants
- De-Bottlenecking of “Thermally Challenged”  
Plants

# **WSAC is a Closed Loop** **Cooling System**

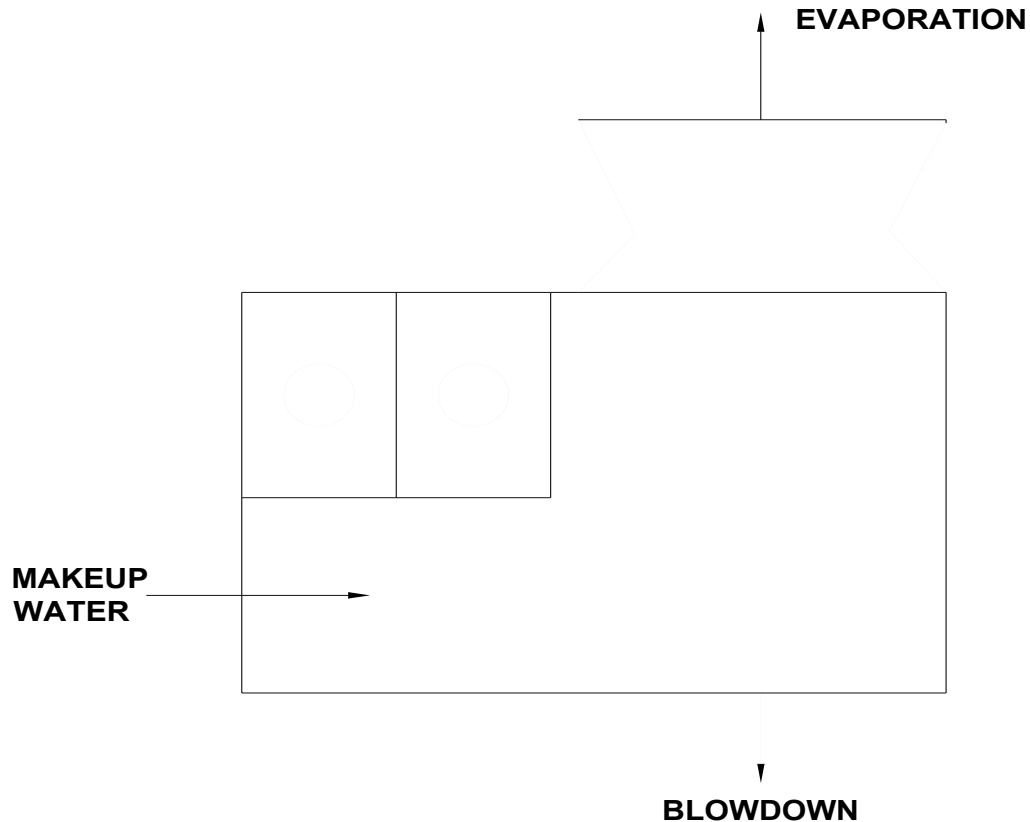
- Process fluid stays inside the tubes
- Open-Loop water never contaminates system
- Open-Loop uses a “Flooded Spray System”
- Wide tube spacing
- Higher cycles of concentration
- Poor Quality Water can be used as makeup source
- Maintains Thermal Performance
- Eliminates Maintenance on Closed-Loop
- Minimal (Easy) Maintenance

# **Water Issues**

- **Evaporation**
- **Cycles of Concentration**
- **Drift**
- **Plume**
- **PM10**
- **Water Makeup Quality**



# Water Issues



$$\text{EVAPORATION (GPM)} = \text{HEAT LOAD (Btu/hr)} / 500,000$$

$$\text{MAKEUP} = \text{EVAPORATION} + \text{BLOWDOWN}$$

$$\text{CYCLES OF CONCENTRATION} = \text{MAKEUP} / \text{BLOWDOWN}$$

# Water Issues

- Drift
  - Based on Spraywater Rate
  - “Standard” drift .02%
  - Drift Eliminators Easily Incorporated
    - .005% standard (with drifts)



# **Water Issues**

- Plume
  - Visual Discharge: Vapor Condensing in Atmosphere
  - Plume Abatement available for Visually or Environmentally Sensitive Areas
- Plume Control
  - Cold Air Introduction
  - Partial Wet / Dry Operation
  - Reheat Coils

# **Water Issues**

- PM10
  - WSAC Meets or Exceeds PM 10 Requirements
  - Lower Total Emissions
  - Lower Discharge Height
- Zero Discharge Plants
  - WSAC used as a 1st Stage Evaporator

## **Water Sources**

- Blowdown from other Cooling Towers
- Blowdown from other systems (R/O, Demin, HRSG)
- Water Treatment Plant Effluent
- Brackish, Seawater

## **Advantages of WSAC for Sites with Poor Quality Makeup Water**

- Spray Water on the exterior surface of the tubes, not inside Heat Exchanger
  - Ability to run Higher Cycles of Concentration
- Co-Current Flow of Water and Air
  - Even Distribution of water over the Tubes
- Unit Material Selection Based on Makeup Water Quality
  - Stainless, Titanium, Brass, Galvanized Steel



# **WET / DRY SYSTEMS**

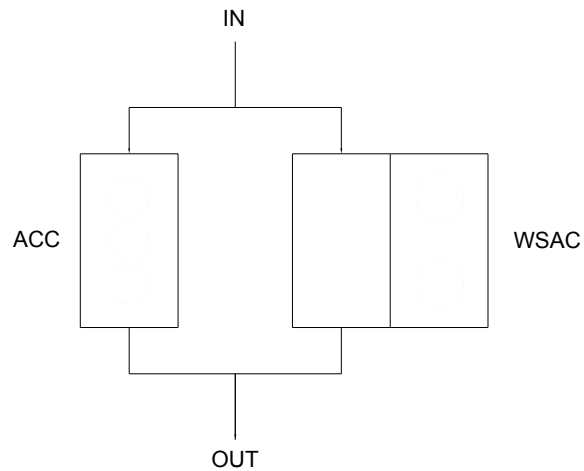
# **Wet / Dry Aux Loop Coolers** **and Steam Condensers**

A Cooling/Condensing Unit that  
Offers the Combined Advantages of:

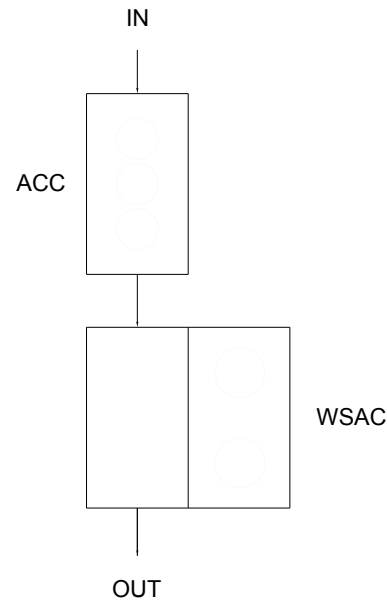
- Dry (Air Cooled) Cooling Mode for  
Colder Ambient Temperatures
- Evaporative (Wet) Cooling Mode for  
Hotter Ambient Temperatures

# Wet / Dry System Options for Water Limited Plants

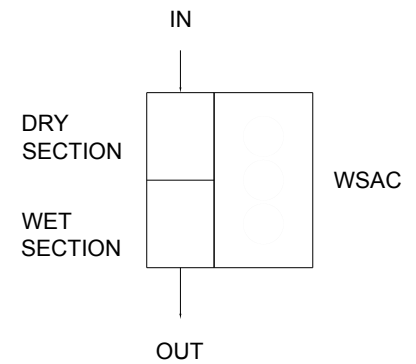
PARALLEL FLOW



SERIES FLOW

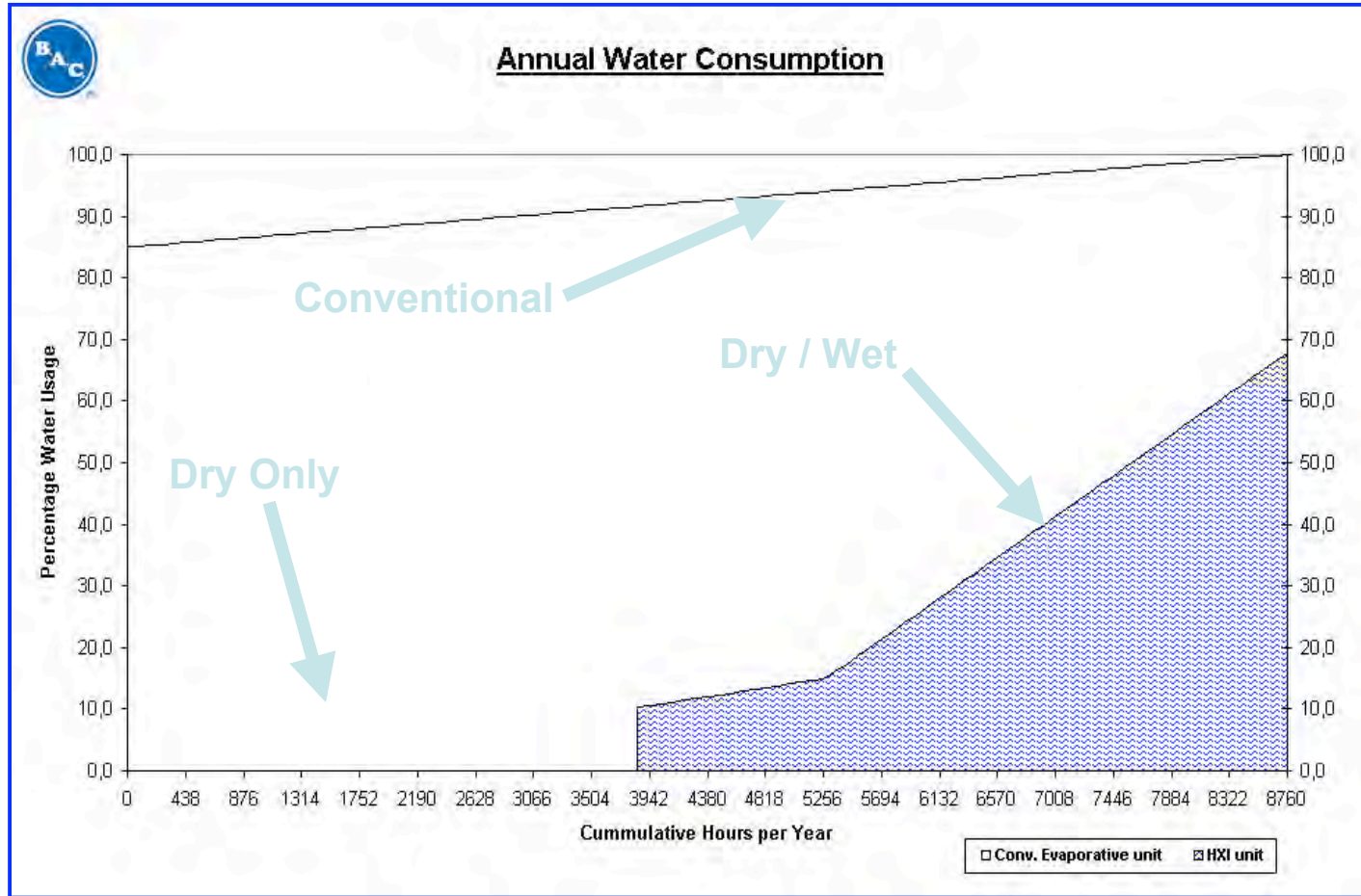


COMBINED FLOW



# Water Usage Graph

Percentage Water  
Use



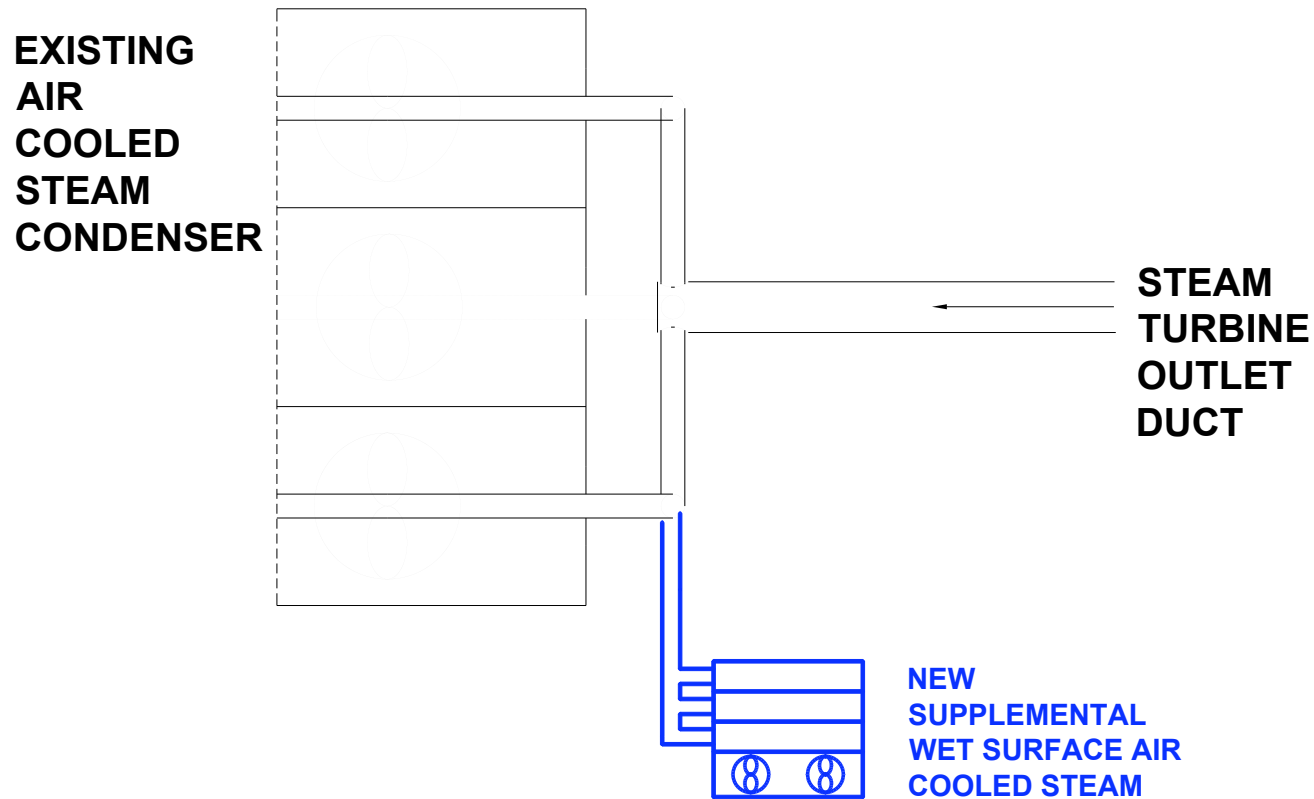
Cumulative Hours per  
Year

## **Advantages of Wet / Dry Aux Coolers and Condensers**

- Reasonable First Cost
- Single Source Thermal Responsibility
- Low Process Outlet/Condensing Temps
- No Plume in Cold Weather
- Low Annual Horse Power Consumption

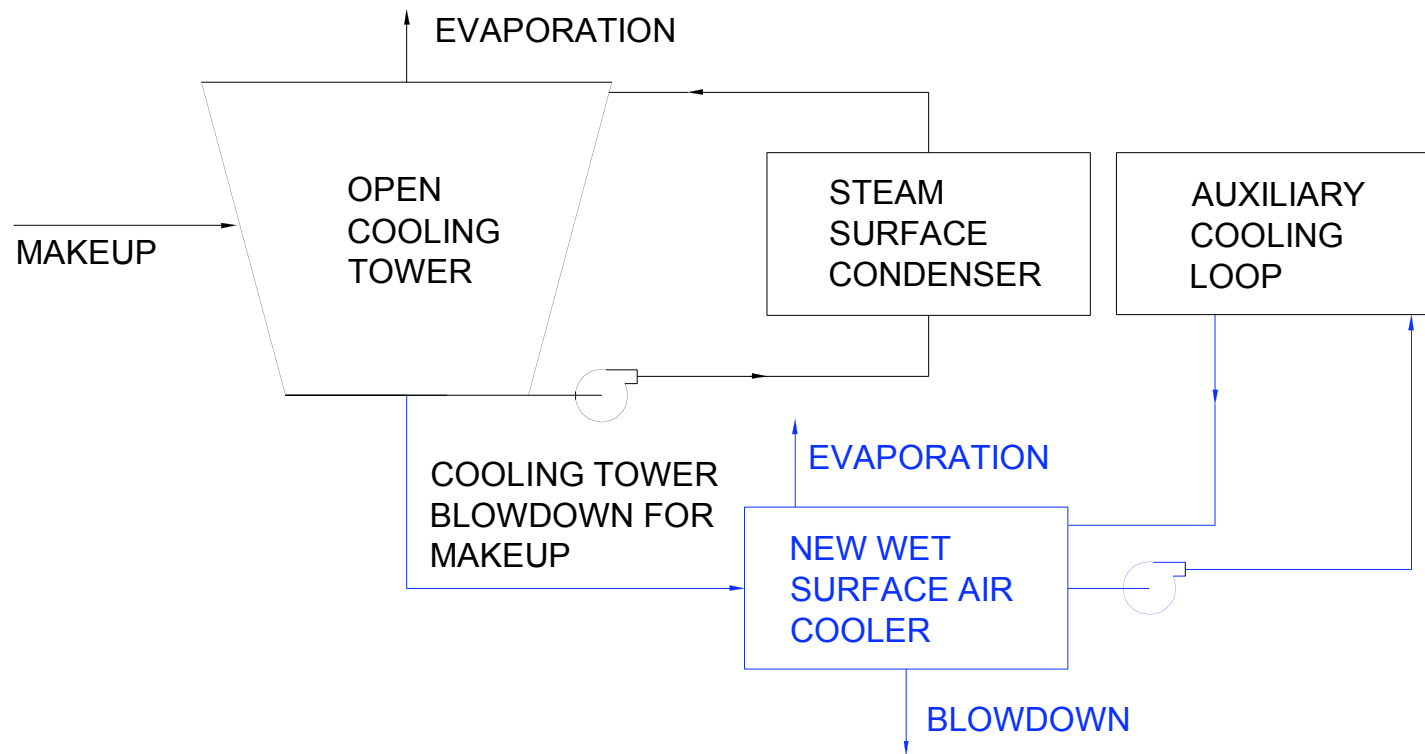
**UP TO 70% ANNUAL WATER REDUCTION**

# De-Bottlenecking of Existing Air-Cooled Systems

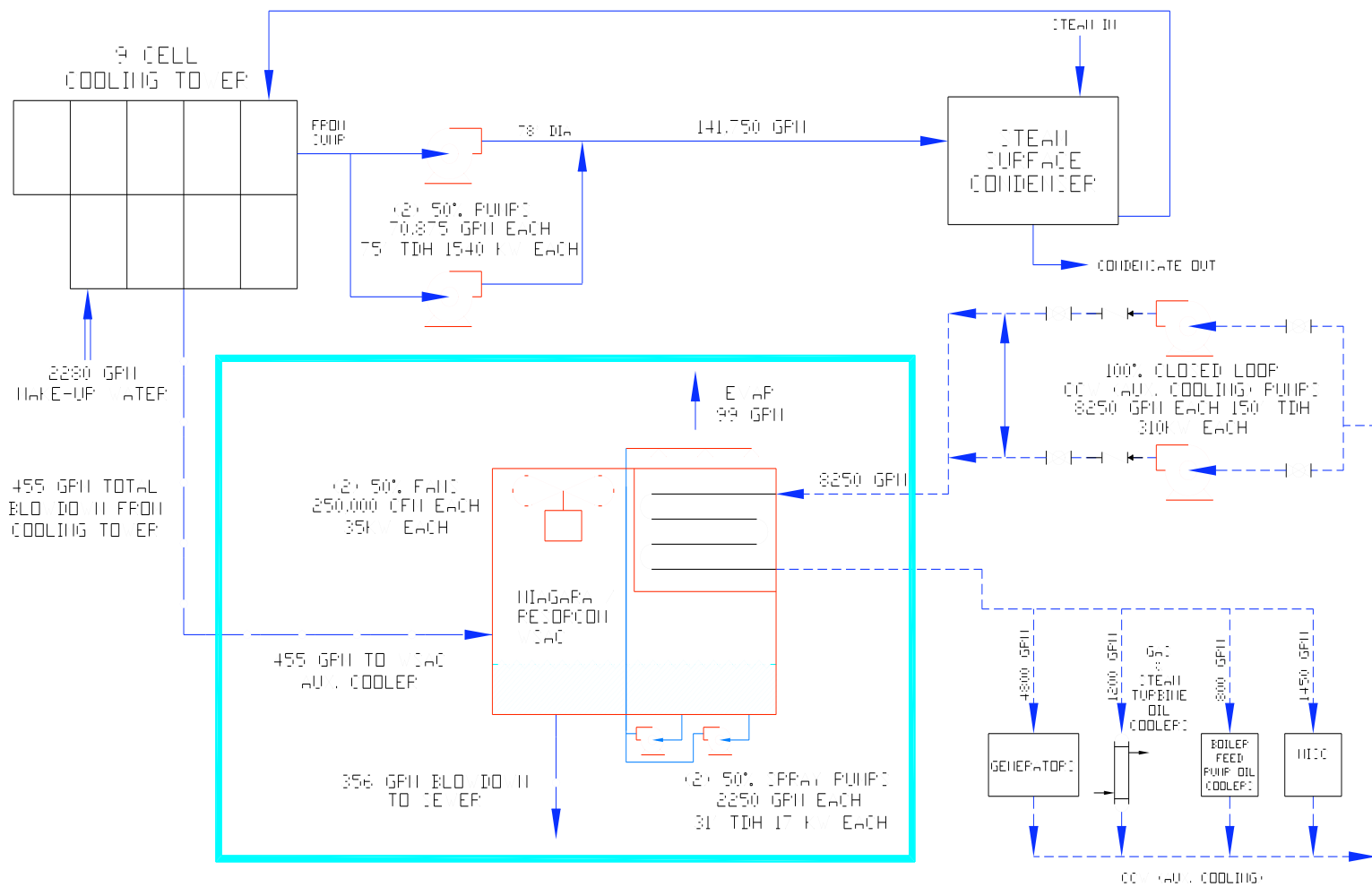




# De-Bottlenecking of Existing Open Loop Systems




# WSAC AUX WATER COOLER



- NOTED: 1. SOLID LINE: DENOTE OPEN LOOP COOLING STEP  
2. DASHED LINE: DENOTE CLOSED LOOP COOLING STEP  
3. DOUBLE LINE: DENOTE HEAT-UP STEP  
4. CIRCLE LINE: DENOTE BLD DO II STEP

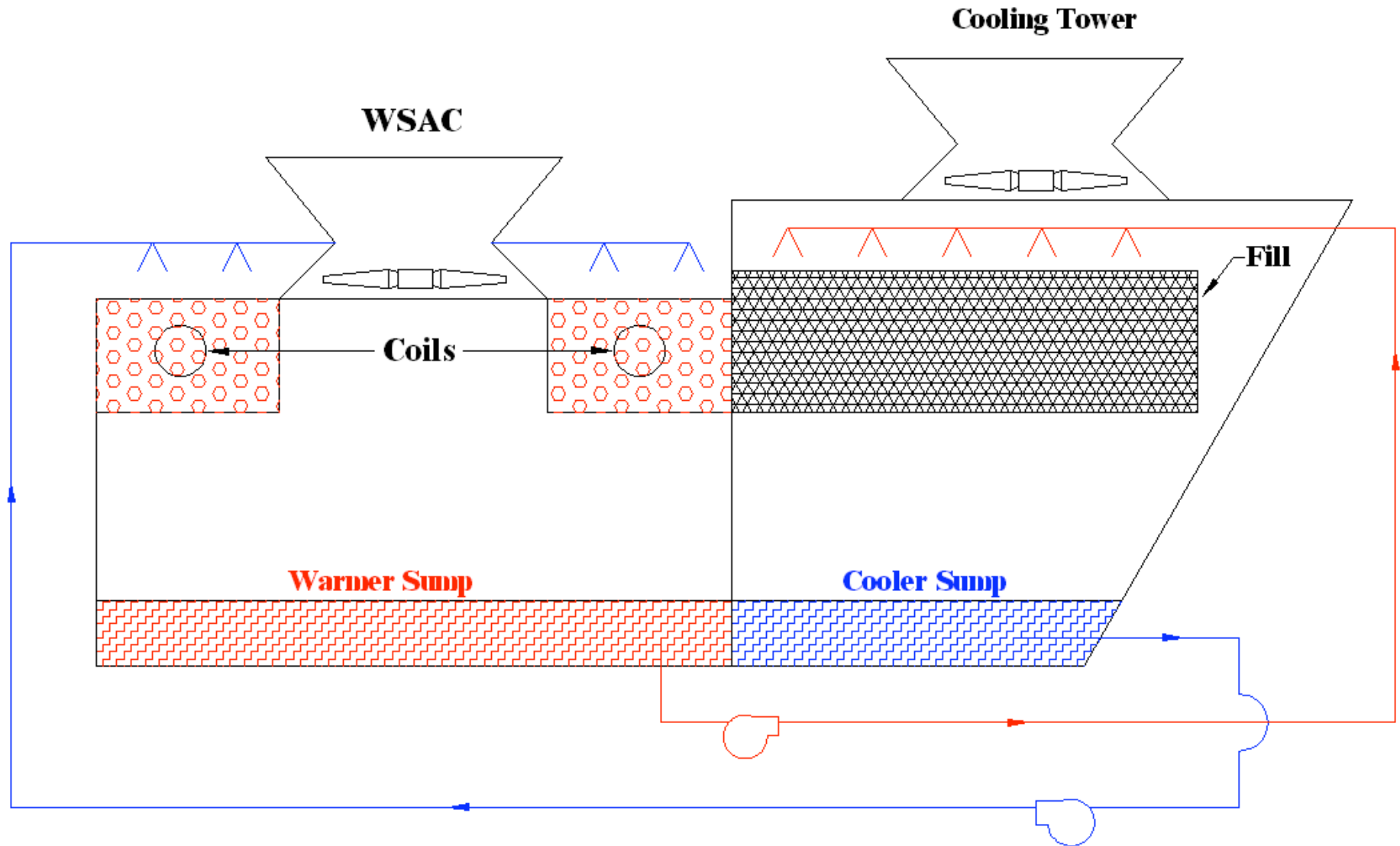
FE 11011	LOC 11011	H-DE	CHG 11011	DATE	FE 11011 OF ADDITION

APPROVAL SIGNATURE:	DATE:	UNIT TAG NO.	 <b>Hogdon Bloer Company</b> ENGINEERED HEAT TRANSFER SYSTEMS BUFFALO, N.Y. 14203	
DESIGN BY:	E	9/30/93	EXPLANATION:	
CHECKED BY:			SHOP DRAWING NO.	UNIFORMITY USE, MANUFACTURE OF PERFORATION EITHER BY: HOLE OF PUNCH, PERFORATED BY DRILL AND/OR AND OTHERS INCLUDING: PROPERTY OF HOGDON BLOER COMPANY.
ENGINEER:			DRAWING TITLE:	
			DRAWING NO.	COINTEGRATED COOLING COIL FOR PLANT
REVIEWED BY:			DATE WHEN ASSEMBLY FIRST USED:	OUTSIDE AIR-TEMPERATURE COOLING SYSTEM
APPLICABLE SPECIFICATION:			SCALE:	
			NO. OF SHEETS:	1 OF 1
			DATE:	
			BY:	
			FOR:	

F: ... HfInGaPn 60K, COOLING CYC. 4		1380
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# “Combined Flow”

## Wet Surface Air Cooler

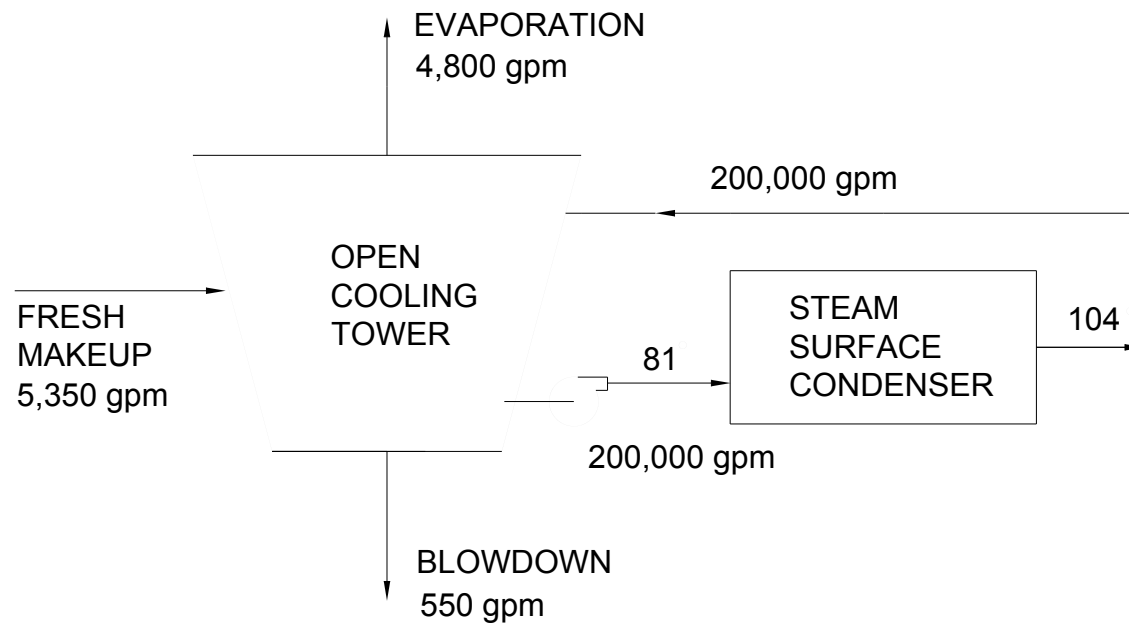


# **RESOURCE CONSERVATION**

# EXISTING STEAM CONDENSING SYSTEM

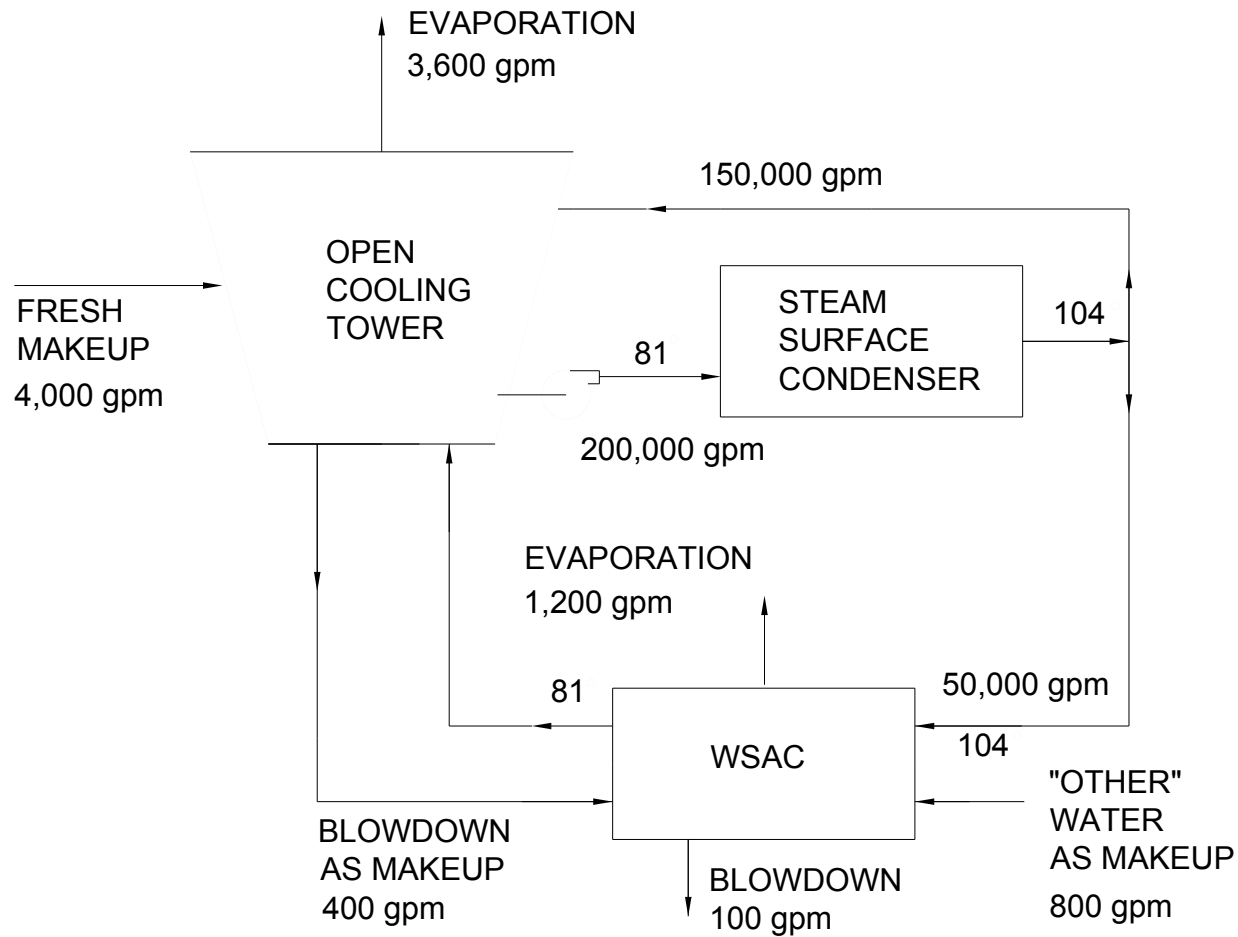
## 550MW COOLING TOWER

**200,000 GPM - 104° IN / 81° OUT**



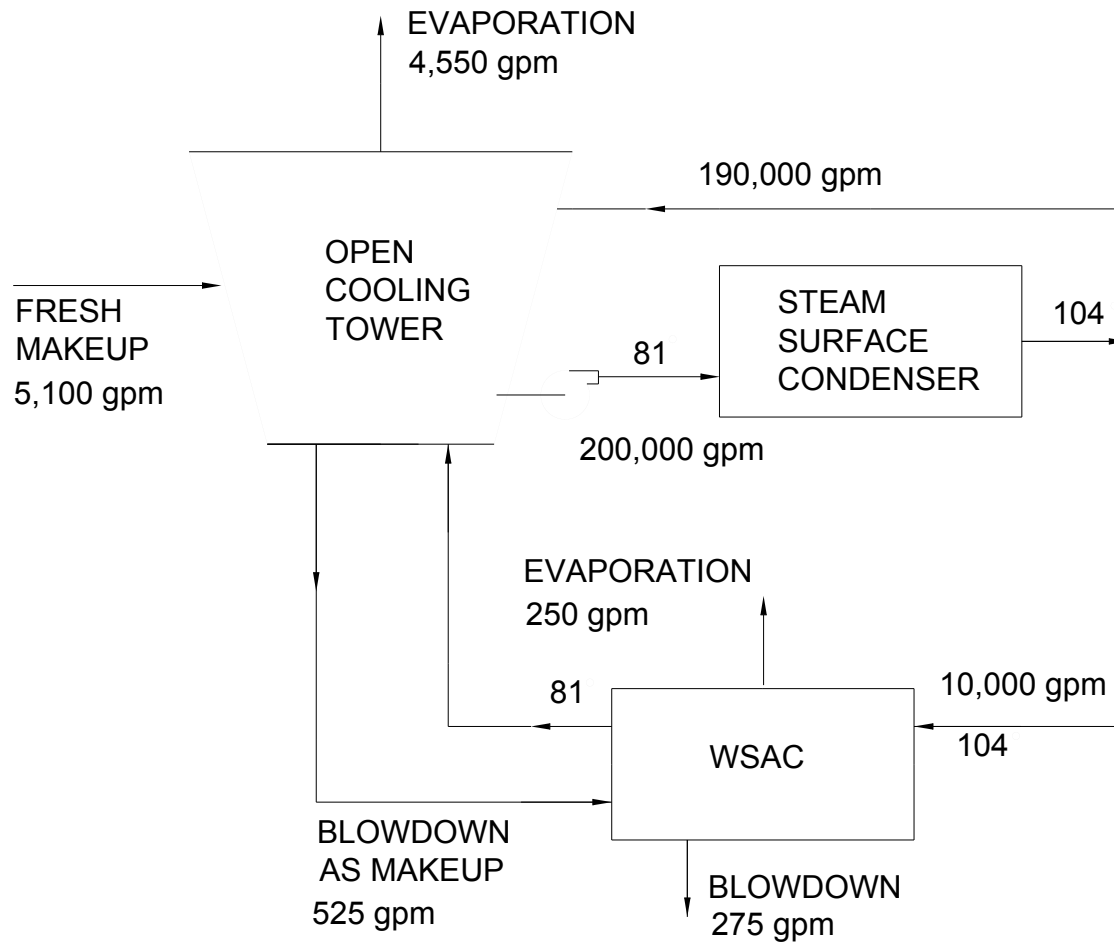
# 25% FRESH WATER REDUCTION

- SAVINGS:      **650 MILLION GALS/YR FRESH WATER**  
                 **220 MILLION GALS/YR BLOWDOWN**





# 5% FRESH WATER REDUCTION



## **5% FRESH WATER REDUCTION**

### MAKEUP WATER SAVINGS

5,350 gpm → 5,100 gpm = 250 gpm

**120 MILLION gal/yr**

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### BLOWDOWN WATER REDUCTION

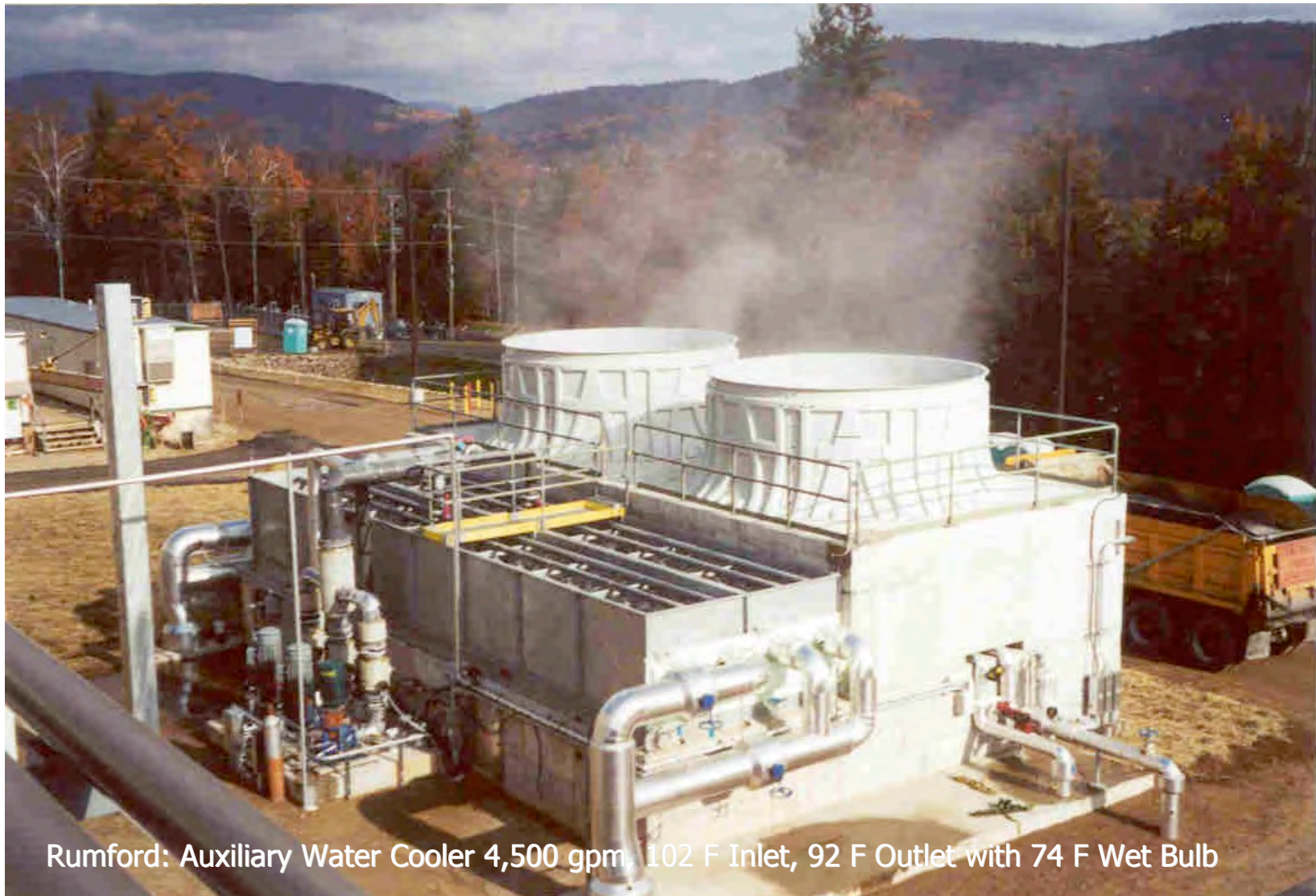
550 gpm → 275 gpm = 275 gpm

**132 MILLION gal/yr**

**\$\$ COSTS FOR:  
WATER ...DISPOSAL...TREATMENT**

# **INSTALLATIONS**

# Large Erect in Place WSAC Fluid Coolers



Rumford: Auxiliary Water Cooler 4,500 gpm, 102 F Inlet, 92 F Outlet with 74 F Wet Bulb

# 37.5 MW Steam Condenser





# 5 MW Cogeneration Plant Virginia, U.S.A.





**Delaware, U.S.A.**  
**Steam Condenser - 18 MW Cogeneration**



# 50 MW Turbine Aux Loop Cooler





# “PLUG & PLAY”



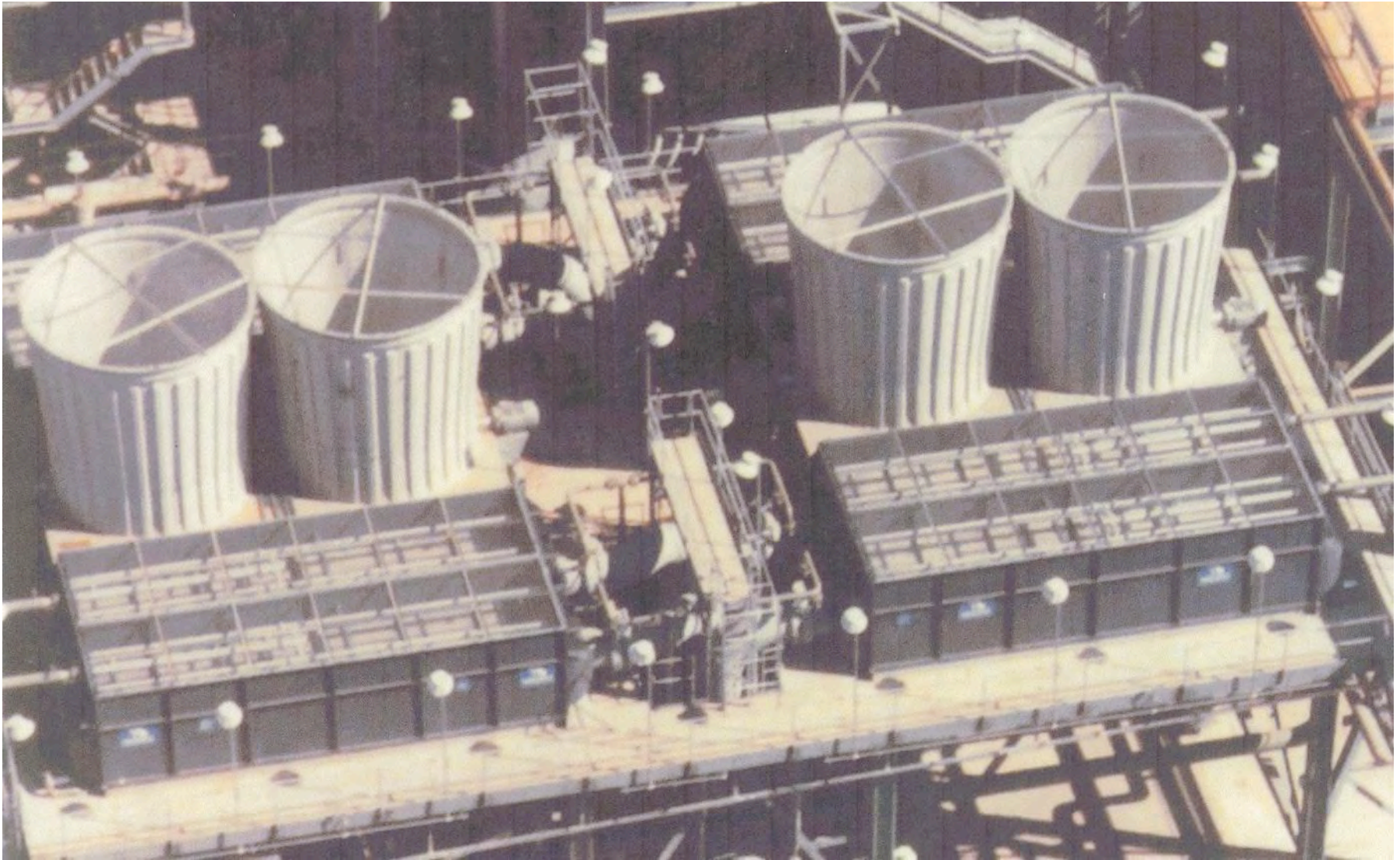


# Factory Assembled Frame Turbine Auxiliary Fluid Cooler





# Steam Condenser With Remote Basin

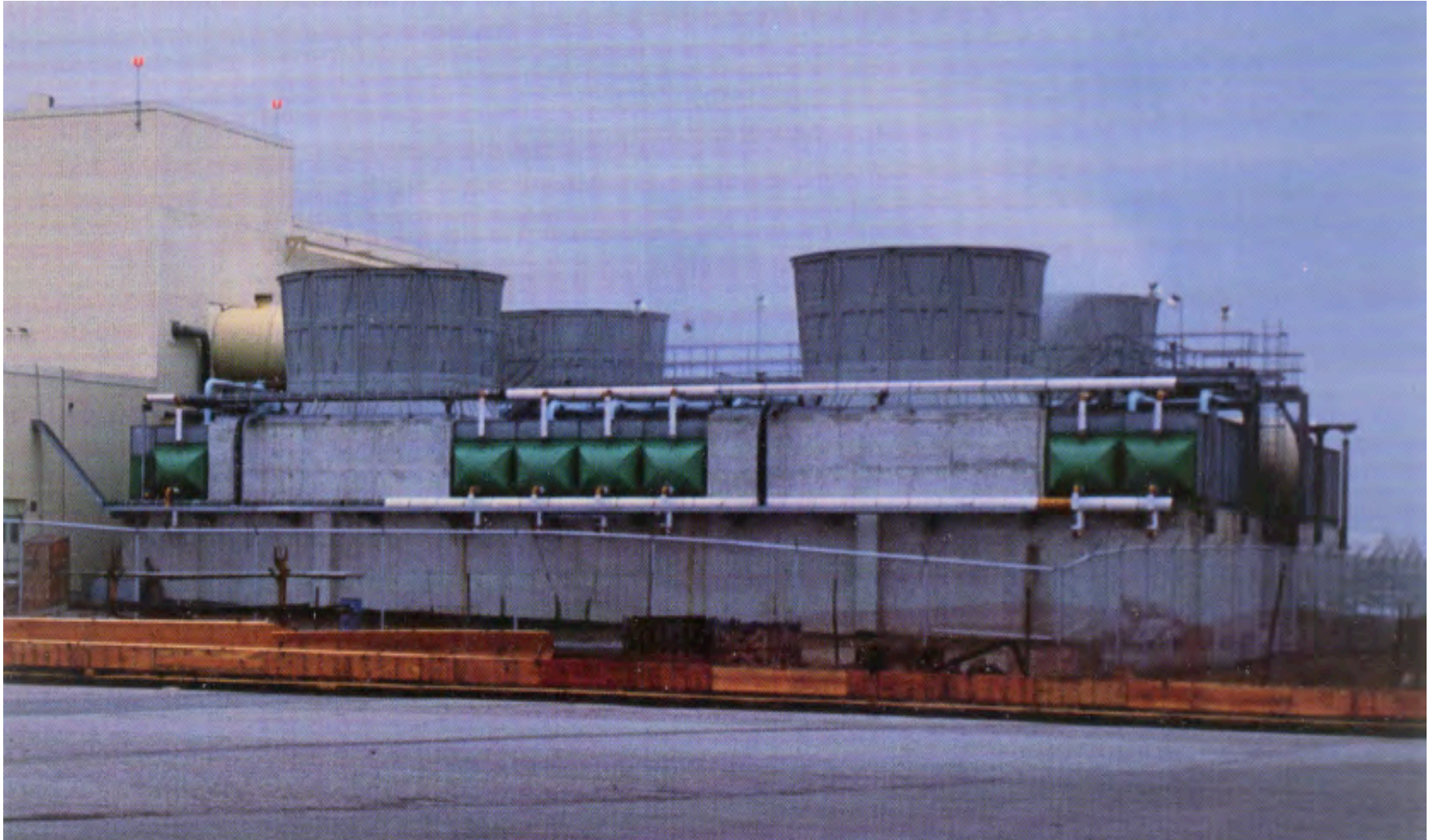


# **670,000 lb/hr Steam Condensers and** **Auxiliary Fluid Cooler**





# Steam Condenser



Condensing 240,000 lbs/hr of steam at 2.33"Hg Abs and cooling 1300 gpm of water for auxiliary cooling purposes.



# Aux Cooler for 4 – 50 MW Gas Turbines With 50% Reserve Capacity



# Gas Turbine Inlet Air Cooling Components





# Wastewater Cooler



# **Advantages of Using the WSAC in Simple and Combined Cycle Power Plants**

- Lower First (Installed) Cost
- Less Parasitic Energy Required
- Lower Operating and Maintenance Costs
- Fireproof Construction
- Freeze Protected

# **Advantages of Using the WSAC for Aux Loop Cooling**

- Cooler Fluid Temperature to Turbine and Generator
- Aux Loop can be run independently

# **Advantages of Using the WSAC for Combined Cycle Steam Condensing**

- Direct steam condensing in tube bundles
- Lower Steam Condensing Temperature

# **Advantages of Using the WSAC for Resource Conservation**

- Significant makeup water savings & blowdown reduction
- Maintains system performance with less makeup water
- Allows for additional thermal capacity without “new” water
- “Alternative” sources can be used as makeup
- 1<sup>st</sup> stage evaporator





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